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Analysis of submerged breakwater models using ripple tank

Mutmainnah*
Indonesia Defense University, INDONESIA

Viviq Ardita Wulandari
Indonesia Defense University, INDONESIA

Roman Argus
3B Scientific Expert Industry, GERMAN

Atmadi
Indonesia Defense University, INDONESIA

Raditya Faradina Pratiwi
National Central University, TAIWAN

Imastuti
Indonesia Defense University, INDONESIA

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Abstract

A breakwater is an infrastructure that functions to dampen wave energy. To secure the area directly adjacent to the coast, an effective breakwater model is needed based on the analysis of the dissipation coefficient value (K_d). This study aims to determine a good breaker model based on the K_d value using a ripple tank. The data analyzed were wave heights before and after passing through the breakwaters of the three concrete models whose arrangement was varied. The results showed that the breaker model that is effective in reducing wave energy is the Grooved cube model with holes arranged horizontally based on the resulting small reflection coefficient (K_r) and transmission coefficient (K_t) values and large K_d values.

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INTRODUCTION

Extreme waves are waves that have enormous energy and can destroy anything in their path. To prevent damage to infrastructure and the people who live around the coast from extreme waves, infrastructure is needed that functions to break up large wave energy or usually called a breakwater. The wave energy that is successfully resolved then reaches the beach is not great. So that the risk of beach damage or beach abrasion can be minimized (Dean & Dalrymple, 1991; Reeve et al., 2018).

The problem of ocean waves is very complex; therefore, several techniques are used to analyze the effectiveness of the breakwater. Ocean wave analysis methods commonly used are mathematical models, numerical methods and experimental (laboratory studies). Rupali & Kumar, (2021) developed a mathematical model with an analytical approach using the Helmholtz equation for the application of permeable and impermeable breakwaters. For the same case but using a numerical method is presented to see the effectiveness of the breakwater by looking at the differences between permeable and impermeable breakwaters, The results show that permeable breakwaters with varying porosity values are more effective than impermeable breakwaters (Qu et al., 2022; Zhou et al., 2023).

***Corresponding Author**
Mutmainnah, Indonesian Defense University, INDONESIA, Email: mutmainnabu@gmail.com

Analytically Liu & Li, (2013) presented a solution of the reflection wave equations and transmission wave equations for porous breakwaters. In general, the effectiveness of the breakwater is shown by the smaller the reflection coefficient (K_r) and transmission coefficient (K_t), and the larger the dissipation coefficient (K_d) (Zheng et al., 2018; Zhao et al., 2021). So, in this study the models presented were then analyzed based on the values of K_r, K_t and K_d.

METHODS

The breakwater model used is shown in Figure 1, namely the cube, Seabee and grooved cube with hole models. The three breakwater models were then tested using a ripple tank by varying their arrangement to see their effectiveness. The data taken is in the form of maximum wave height data (H_{max}) and minimum wave height data (H_{min}) before and after passing through the breakwater model. From the wave height data, it is possible to know the values of K_r, K_t and K_d for each model by varying the arrangement.

Figure 1. Breakwater model (Cube, Seabee and Grooved cube with hole).

Figure 2 is a ripple tank with a water depth of 7 cm, the wave lighter and sensor are placed on opposite sides to the left and right respectively. The frequency of the wave-ignition made is 1.95 Hz, obtained from 117 times of igniting the wave per minute with a period of 0.51 s. The wave height sensor is used to determine the physical effects that occur with the light indicator. The wave height sensor has 5 different LED colors namely red, yellow, blue, green, and white. The distance on each led is 0.5 cm. But from the surface of the water to the white led is 0.3 cm, so when the wave height from the bottom of the water surface is 0.8 cm it will turn on the white and green led lights, if the wave height is 1.3 cm it will turn on three leds white, green, and blue. Red led light will turn on when high.

Figure 2. Ripple tank

The effectiveness of the model will be analyzed by looking at the values of wave transmission, wave reflection and wave dissipation which are described as follows (Triatmodjo, 1999):

Wave Transmission

Wave transmission is the transmission of waves through a building. The parameters are expressed as the ratio between the transmitted wave height (H_i) and the incident wave height (H_i) or the root of the transmitted wave energy (E_t) and the incident wave energy (E_i).

$$K_t = \frac{H_t}{H_i} \tag{1}$$

$$H_t = H_r = \frac{H_{max} - H_{min}}{2} \tag{2}$$

Wave Reflection

Wave reflection occurs when an incident wave hits or hits an obstacle so that it is partially or completely reflected. The ability of a breakwater to reflect waves can be known through the reflection coefficient. The parameter is expressed as the ratio between the reflected wave height (H_r) and H_i or the root of the reflected wave energy (E_R) and E_i.

$$K_r = \frac{H_r}{H_i} \tag{3}$$

Dissipation Wave

Dissipation waves are waves that have been successfully suppressed. The magnitude of the wave height absorbed (dissipated) H_d is H_i minus H_r and H_i. The H_i experienced by the breakwater depends on how much H_{max} and H_{min} experienced by the front of the breakwater.

$$K_d = 1 - K_r - K_t \tag{4}$$

RESULTS AND DISCUSSION

Three models of concrete blocks are alternately installed in the middle of the ripple tank pool. The arrangement of the Seabee and Grooved cube with hole concrete block models varies horizontally and vertically based on the holes the concrete blocks have against the wave triggering device. Variations in the arrangement of concrete blocks are then analyzed by taking H_i, H_r and H_t data, each of which depends on H_{max} and H_{min}. From the wave height data to see the effectiveness of the three concrete block models, the values of K_r, K_t, and K_d were calculated.

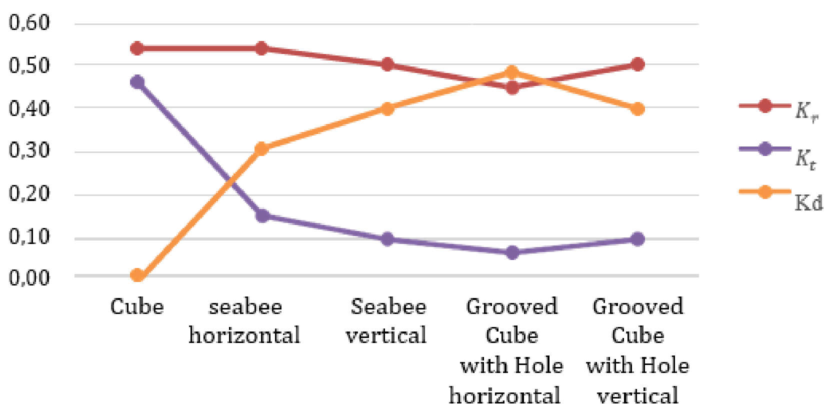

Figure 3. Graph of the relationship between the values of K_r ,K_t, and K_d to the three-base stacking solving model

Figure 3 shows that of the three concrete block models, the cube model is the model that has the highest K_r and K_tvalues while the K_d value is zero, meaning that the model is not effective in

reducing wave energy. For seabee concrete blocks and grooved cube with holes, based on their arrangement, the most effective in reducing wave energy is the horizontally arranged grooved cube with holes model. This is because this model has a large K_d value of 0.48 compared to the Seabee model and has the lowest K_r and K_tvalues of 0.45 and 0.7. Based on the data analysis, it can be concluded that the concrete block model with holes is more effective in reducing wave energy than the concrete block model without holes.

Figure 4. Models by stacking 2 layers

Subsequent experiments compared the seabee and grooved cube with hole models by stacking 2 layers of concrete blocks to see the effect of the number of holes in the concrete blocks on the values of K_r, K_t, and K_d. Seabee model concrete blocks and grooved cube with holes are arranged as shown in Figure 4.

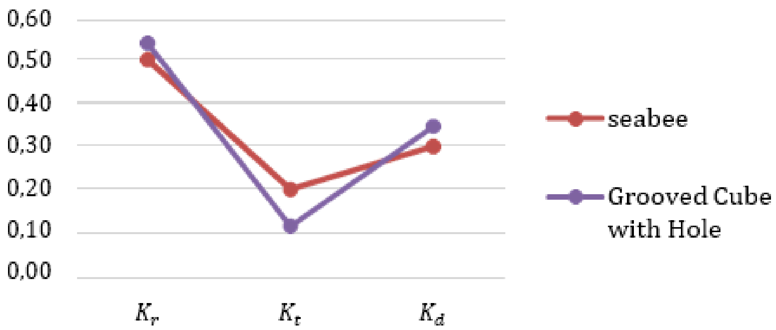

Figure 5. Graph of the relationship between the values of K_r ,K_t, and K_d to 2 layers of concrete blocks

The effect of the number of holes in the concrete block on the K_t value can be seen in Figure 5 where the Seabee model which has fewer holes than the grooved cube with holes model has a K_t value which is also small compared to the grooved cube with holes model, the difference in value is around 0.1. Meanwhile, the K_r value is not compared to the number of holes in the concrete bend, but is used as a parameter to get the K_d value. The results show that the grooved cube with holes model, which has more holes, has a higher K_d value than the Seabee model's K_d value, with a difference that is not much different, namely 0.05.

CONCLUSION

The breaker model that is good at reducing wave energy based on the dissipation coefficient value is the grooved cube with holed model. This is because this model has more holes/pores than the seebea model so that the reflection coefficient and transmission coefficient are smaller and the dissipation coefficient value is enlarged.

Further research must be conducted by analyze breakwater model geometry by calculate density using Maxwell equation for more precise results. It can also be done by paying attention to other related parameters such as fluid flow and pressure.

AUTHOR CONTRIBUTIONS

Each author of this article played an important role in the process of method conceptualization, simulation, and article writing.

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